Mark schemes

1

(a) three parallel rays refracting through objective **(1)**
rays pass through intermediate image at point labelled F_o, F_e with $f_o > f_e$ **(1)**
rays leave eyepiece parallel to construction ray (which need not be shown) **(1)**

3

(b) (i) separation (= $f_o + f_e$) = 0.10 + 0.50 = 0.60 m **(1)**

(ii) (use of $m = \frac{f_o}{f_e}$ gives) $m = \frac{0.5}{0.1} = 5$ **(1)**

$\alpha = m\alpha = 5 \times \frac{3500}{380000} = 0.046$ rad **(1)**

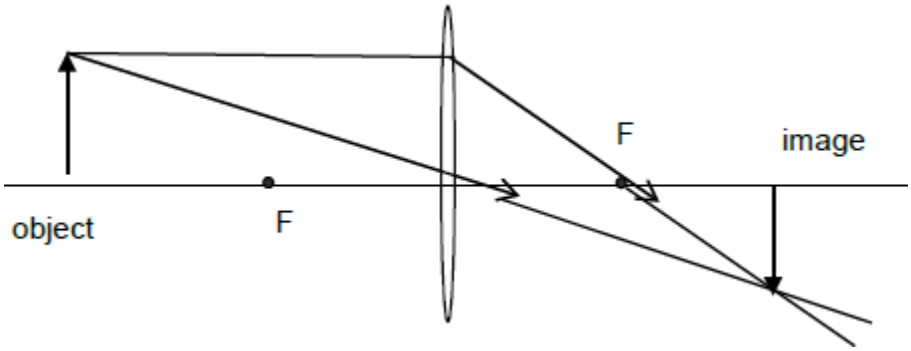
[or $\alpha = \frac{3500}{380000}$
$\alpha' = 5\alpha = 0.046$ rad]

(iii) edges of the image will appear coloured **(1)**

4

[7]

2 (a)



Arrows are not essential

Condone only one focus if it is the one used for the construction ray.
Construction ray must have focus labelled to get the mark.

Lose the second mark if the image is same size or magnified

Image line is needed for second mark.

One construction ray correct ✓

Other construction ray to form diminished image ✓

(The parallel construction ray must pass through a labelled F)

Object, image labelled correctly. ✓

3

(b) u = 128 cm

Allow c.e. for incorrect v

v = 200 − 128 = 72 cm ✓

Condone u and v the wrong way round.

Use of 1 / f = 1 / u + 1 / v

To give 1 / f = 1 /128 + 1 / 72

f = 46 cm ✓

2

(c) Objective.

No credit for unsupported answer.

As M = fo / fe, for magnification fo > fe ✓

As telescope length = fo + fe, lens must be objective (so that telescope not too long.) ✓

2

[7]

3

(a) 3 parallel off-axis rays through objective lens correct **(1)**

rays continued through to the eyepiece emerging parallel to construction line **(1)**

correct position of labelled foci **(1)**

3

(b) (i) use of $f_o + f_e = 3.7$

and $f_o/f_e = 50$

(to give $51f_e = 3.7$) **(1)**

$f_o = 3.6$ (m) and $f_e = 0.074$ (m) **(1)**

2

(ii) use of $s = r\theta$

to give $\theta = 23/380000 = 6(.053) \times 10^{-5}$ rad **(1)**

use of $M = \theta_2/\theta_1$

to give $\theta_2 = 50 \times \theta_1 = 3(.026) \times 10^{-3}$ (rad) **(1)**

2

(c) diagram to show dispersion of different colours in the correct order **(1)**
rays crossing each other or principal axis correctly **(1)**

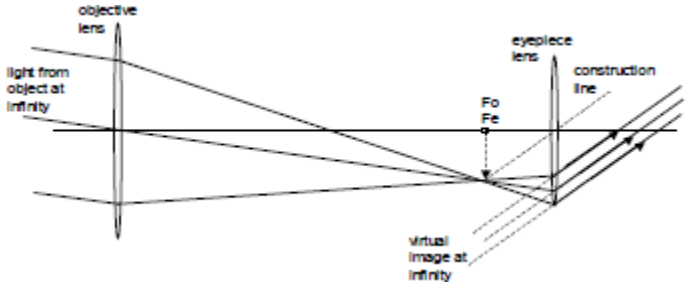
2

[9]

4

(a) Both focal points labelled, on the principal axis, and coincide, with fo>fe ✓
Three <u>off-axis</u> rays through objective lens correct ✓
Three rays through eyepiece correct, parallel to a construction line. ✓

Accept point or length labelled. Allow single point F.
Ignore labels outside the space between the two lenses.
Rays must be off-axis to get the second mark.
Construction line does not need to be drawn.
If only 2 rays drawn, or there is no principal axis, max 2.



3

(b) (i) Using
$f_o + f_e = 21$
$f_o / f_e = 210$ ✓

Evidence of both equations needed for the mark.

Gives
$211\ f_e = 21$
$f_e = 21 / 211 = 0.10$ m
and $f_o = 21$ m (20.9) ✓

Alternative: $f_o = 4410 / 211 = 0.10$ m
If 210 used rather than 211 in substitution, max 1.
If the correct answer is obtained by inspection, max 1.

2

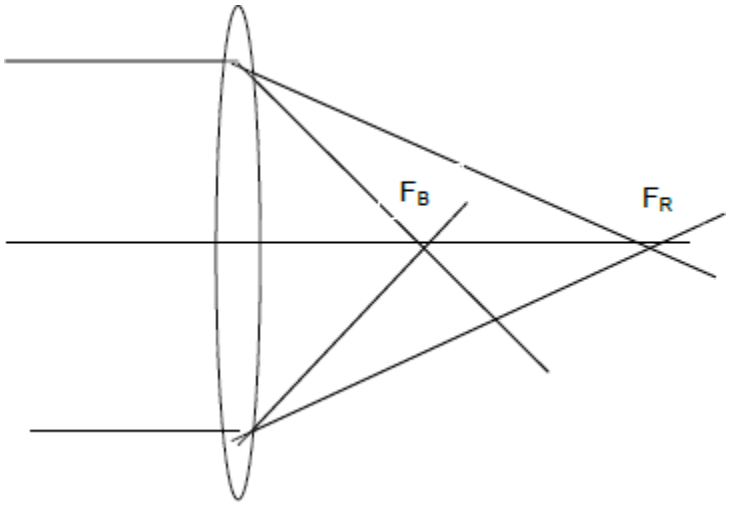
(ii) Large diameter allows fainter objects to be viewed,
(as the collecting power is proportional to d^2) ✓
Larger diameter allows better resolution (as smallest resolvable angle is proportional to 1 / d)✓

Allow: more light, better collecting power, brighter image, able to see more distant objects (not just further).
Allow references to more detail or clearer images for this mark.
Ignore references to magnification or field of vision.

2

(c) Diagram showing two focal points with blue focal point closer to lens than red focal point.

Colours must be labelled. Allow wavelengths or frequencies if correct way round.
Rays need to be focused.
Allow 1 ray for each colour if principal axis drawn and foci labelled.
If other colours included, they must be correct.
Allow violet for blue.
Incident rays do not need to be parallel to the principal axis.



1

[8]

5

(a) (i) (use of $\theta = \frac{\lambda}{d}\lambda$ gives) $\frac{\theta_{reflector}}{\theta_{refractor}} = \frac{d_{refractor}}{d_{reflector}}$ **(1)**

$= \left(\frac{0.9}{1.52}\right) = 0.59(2)$ **(1)**

(ii) use of, energy collected per sec $\propto$ = area $\propto = d^2$ **(1)**

$\frac{P_{refl}}{P_{refr}} = \left(\frac{d_{refl}}{d_{refr}}\right)^2 = \left(\frac{1.52}{0.9}\right)^2 = 2.85$ **(1)**

3

(b) (i) correct diagram showing four parallel co-axial rays, with outer rays brought to focus at a point closer to mirror than inner rays **(1)**

(ii) (use of) parabolic mirror **(1)**

2

(c) (i) correct diagram showing two mirrors, one concave, one convex **(1)**

(ii) mirror blocks light so less light hits objective mirror **(1)**
light diffracted passing secondary mirror affects image **(1)**

3

[8]

6

(a) diagram to show:
both focal points coinciding and labelled, with $f_o > f_e$ **(1)**
centre ray straight through objective, rays crossing at focal plane and proceeding to eyepiece **(1)**
rays refracted at eyepiece and emerge parallel to construction line **(1)**

3

(b) (i) ($f_o + f_e = 3.5$, and $f_o / f_e = 100$) estimate $f_o \approx 3.5$ m and $f_e \approx 0.035$ m **(1)**

(ii) (use of $M = \frac{\alpha}{\alpha}$ gives) $\alpha = \frac{4.0 \times 10^{-3}}{100} = 4.0 \times 10^{-5}$ (rad) **(1)**

(use of $\alpha = \frac{D}{r}$ gives) $D = 4.0 \times 10^{-5} \times 1.3 \times 10^{9} = 5.2 \times 10^{4}$ km **(1)**

(allow C.E. for value of α)

3

(c) no chromatic aberration - mirrors do not refract light **(1)**
no spherical aberration - use of parabolic mirror **(1)**
no distortion - mirror can be supported more strongly **(1)**
better resolving power or greater brightness - mirrors can be larger **(1)**
more light gets through (image brighter) - lens absorbs more light **(1)**
(any two)

2

[8]

7

(a) diagram to show:
correct curvature of mirrors **(1)**
rays crossing in the hole in the objective mirror **(1)**

2

(b) (i) $\theta\left(=\frac{\lambda}{d}\right)=\frac{2.0\times10^{-6}}{3.8}$ **(1)**

$= 5.3 \times 10^{-7}$ rad **(1)** $(5.26 \times 10^{-7}$ rad)

(ii) visible wavelengths shorter (than infra red) **(1)**
$\therefore$ smaller resolving angle ($\therefore$ better resolving power) **(1)**

4

(c) (i) water vapour **(1)** (or carbon dioxide)

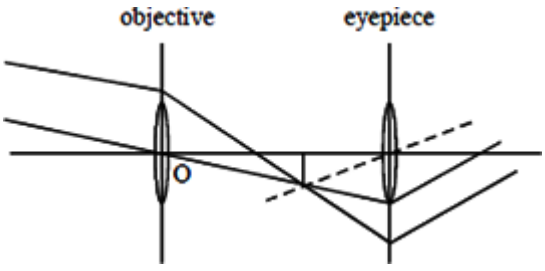
(ii) longer wavelengths absorbed **(1)**
shifts peak of graph to shorter wavelengths **(1)**
star appears hotter [or reference to appropriate equation] **(1)**

max 3

[9]

8

(a) (i)



correct rays through objective **(1)**

first image at f_0 **(1)**

f_0 and f_e coincide **(1)**

correct construction line(s) **(1)**

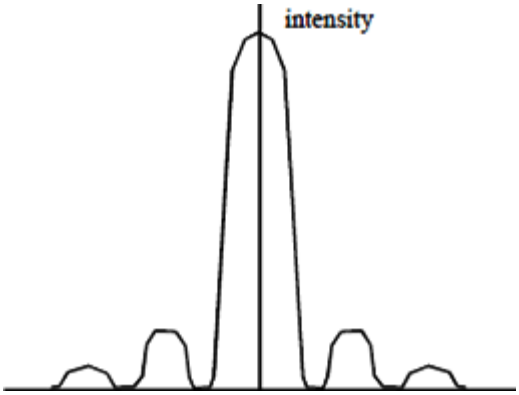
rays emerge parallel **(1)**

(ii) $\left(M = \frac{\alpha'}{\alpha} \text{ gives}\right) 24 = \frac{120}{\alpha}$ **(1)**

α = 5 sec (of arc) **(1)**

(7)

(b) (i)



central maximum **(1)**

decreasing maxima **(1)**

approximate equal spacing between

minima either side of central axis **(1)**

(ii) two intensity curves [or two Airy discs] **(1)**
central maximum of first coincides with
first minimum of second curve **(1)**

(5)

(c) (i) $\left(\theta = \frac{\lambda}{d} \text{ gives}\right) \theta = \frac{6.0 \times 10^{-7}}{15 \times 10^{-2}}$ = 4.0 × 10^{-6} rad **(1)**

angular separation of Mizar 7.0 × 10^{-5} rad, can be resolved **(1)**

(ii) resolving power controlled by diffraction effects [or by $\frac{\lambda}{d}$] **(1)**

hence increasing angular magnification does not increase resolution **(1)**

(4)

[16]

9 (a) (i) F_o, F_e shown coincident **(1)**
objective and eyepiece correctly identified **(1)**

(ii) $M = \frac{2.50}{0.020}$ (=125) **(1)**

β = 6.2(5) × 10^{-3} rad **(1)**

4

(b) (i) convex mirror between objective and F_1 **(1)**

(ii) two rays directed towards F_1 **(1)**
rays cross after reflection **(1)**
emerge parallel from lens **(1)**
label F_2 **(1)**
C shown correctly **(1)**
if plane or concave mirror shown, mark as scheme to max 2 / 6

6

(c) (i) (chromatic aberration -) different wavelengths **(1)**
refracted different amounts [or different speeds in glass] **(1)**
image with coloured edges [or different focus for different colours] **(1)**

(ii) no refraction (by mirrors) [or telescopes use mirrors or no chrom abber by mirr] **(1)**
some chromatic aberration in eyepiece lens **(1)**

5

[15]